Impact of intermittent generation on the operation of power markets

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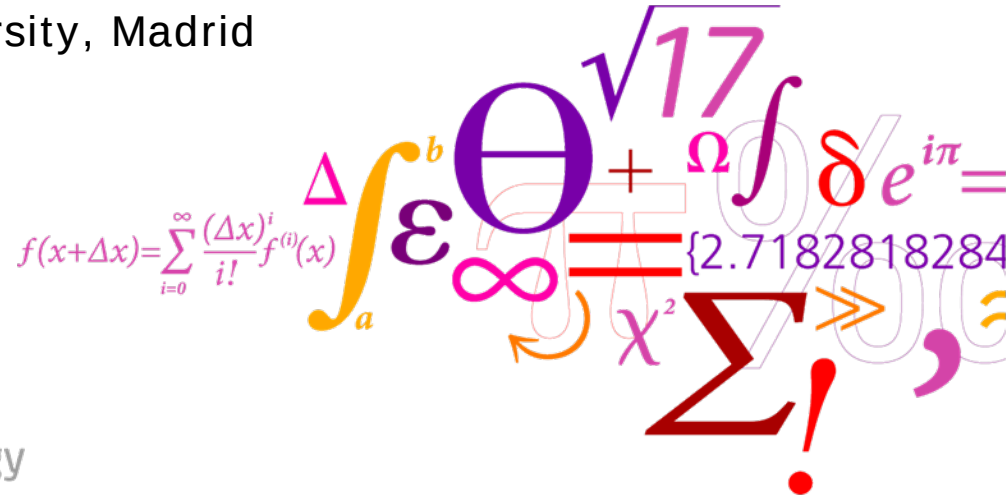


Risø DTU
National Laboratory for Sustainable Energy

Impact of intermittent generation on the operation of power markets

AGENDA

Intermittent generation – uncontrollable generation

Short term effects on markets

- Short term marginal costs
- Day ahead power markets
- Average prices
- Price volatility
- Intermittent renewable generator revenue
- Balancing
- Asymmetry in balancing bidding strategies
- Interaction with other technologies

Long term effects on markets and investment incentives

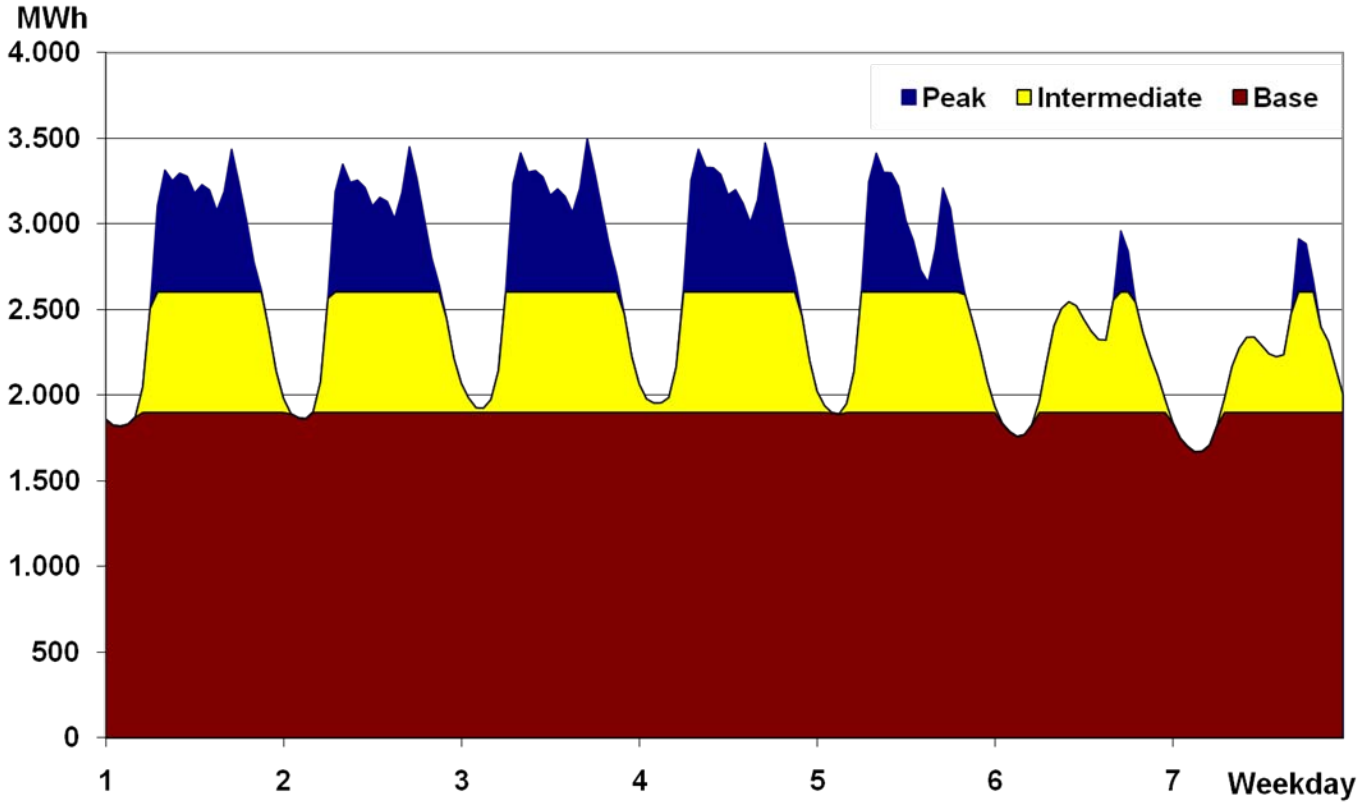
- Subsidies distort the market investment signals
- - on the contrary, the low market price signals that more capacity is **not** needed

Reliability and investment,

Do we really need all the back-up power?

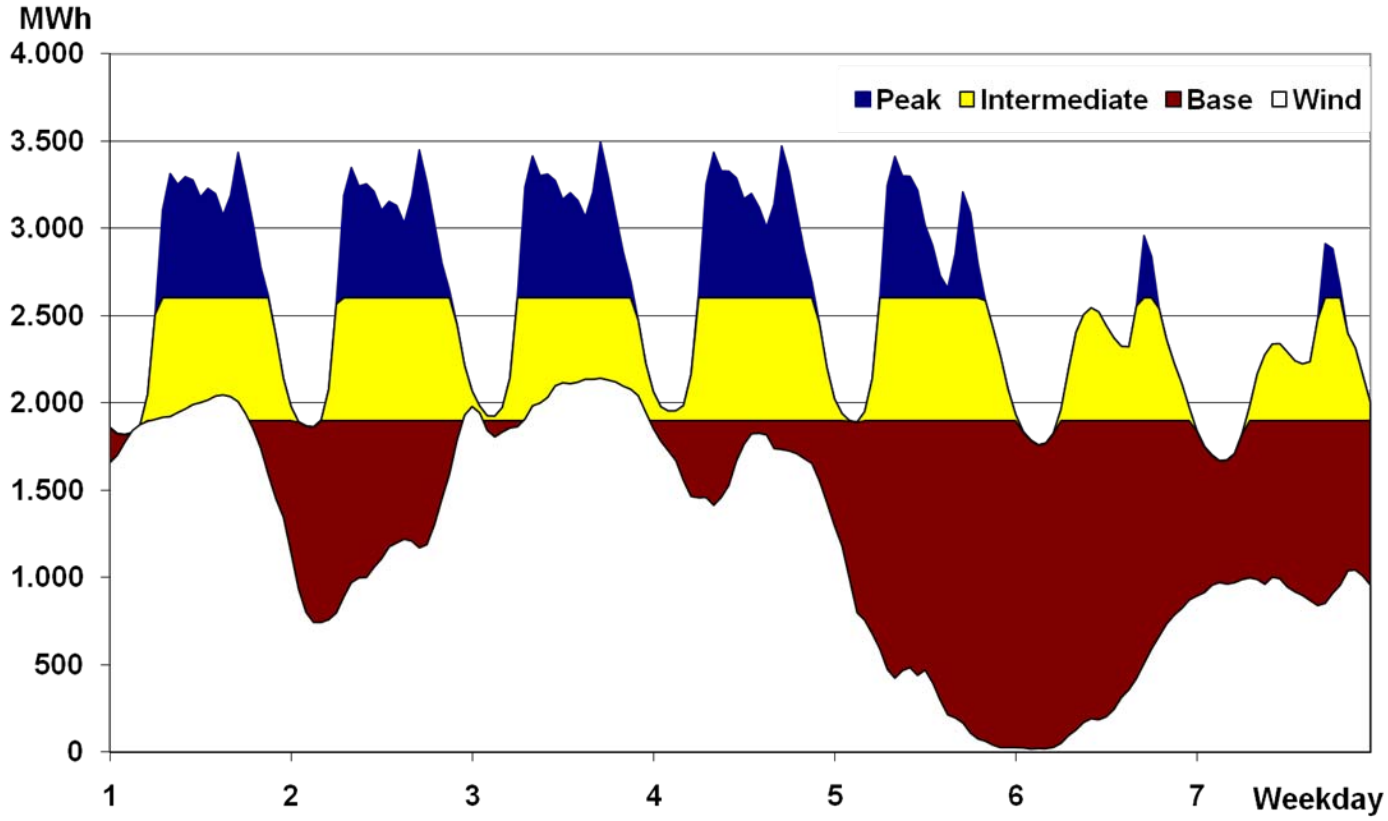
Electricity markets: Covering demand (I)

- traditional: separation into base, peak and intermediate generation
- illustrative example: DK West figures



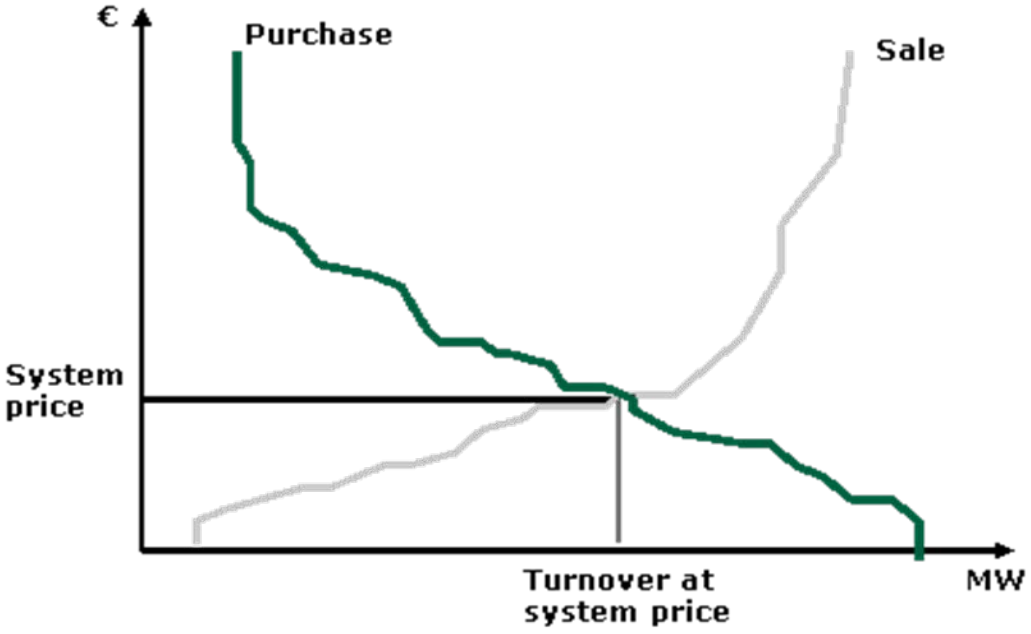
Electricity markets: Covering demand (II)

- now: fluctuating renewables
- illustrative example: Denmark-West, 2nd week 2005



Electricity markets: standard supply and demand

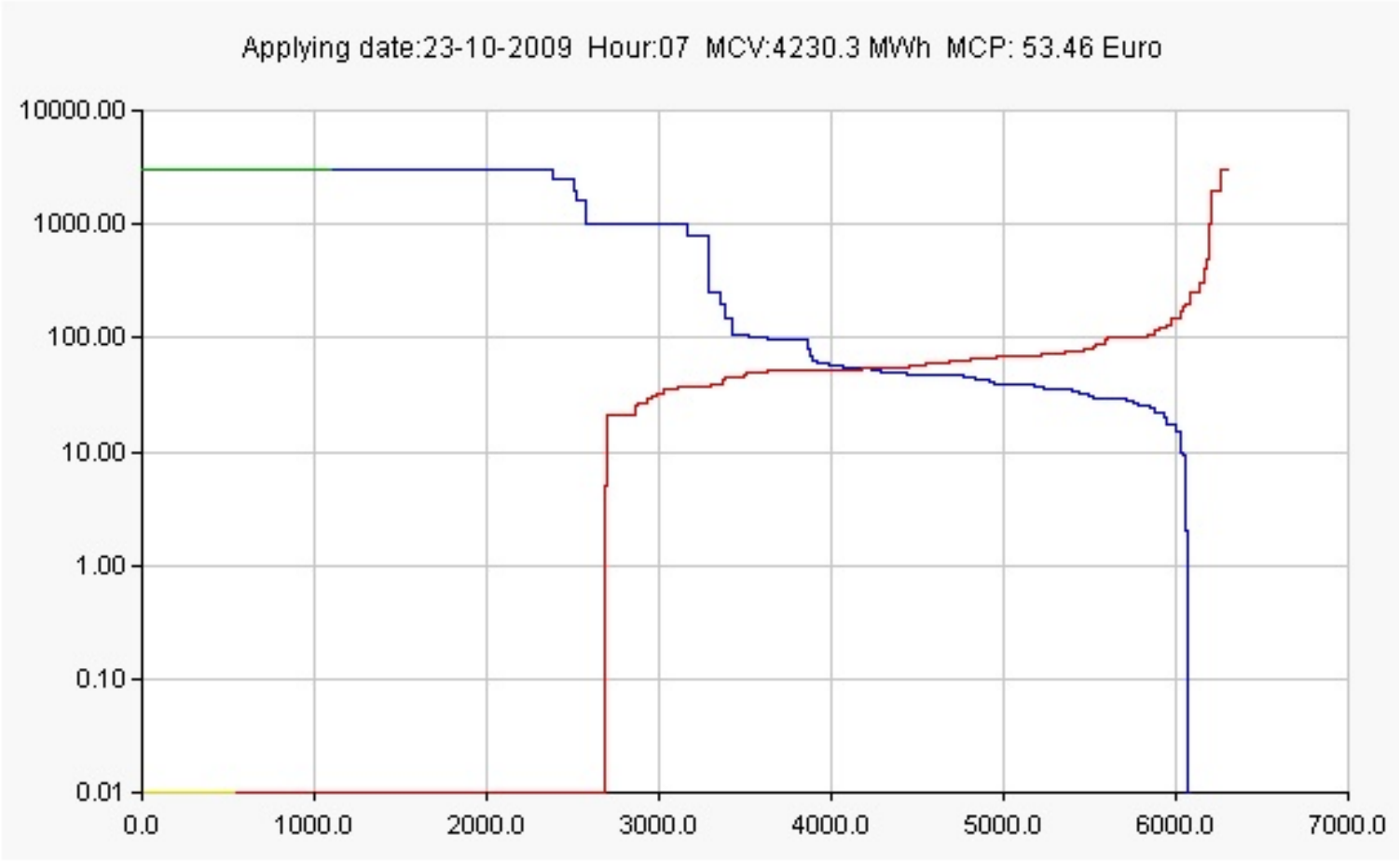
- Spot (day ahead) markets
- Main focus: European spot markets (day ahead), hourly resolution (e.g. Nordpool)
- Buyers and sellers bid *stepped curves*



Nordpool homepage

AGGREGATED CURVES

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 Zoom



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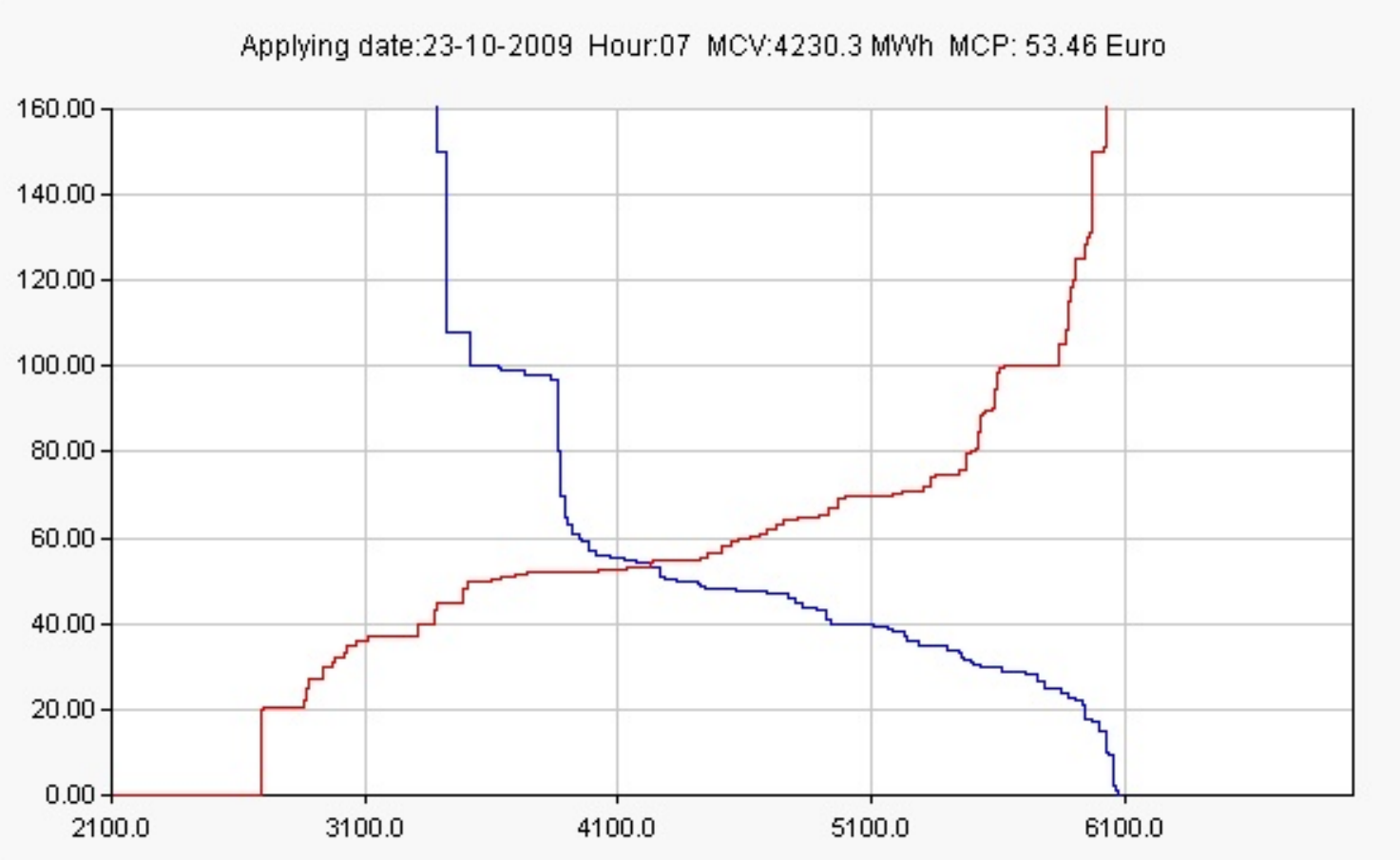
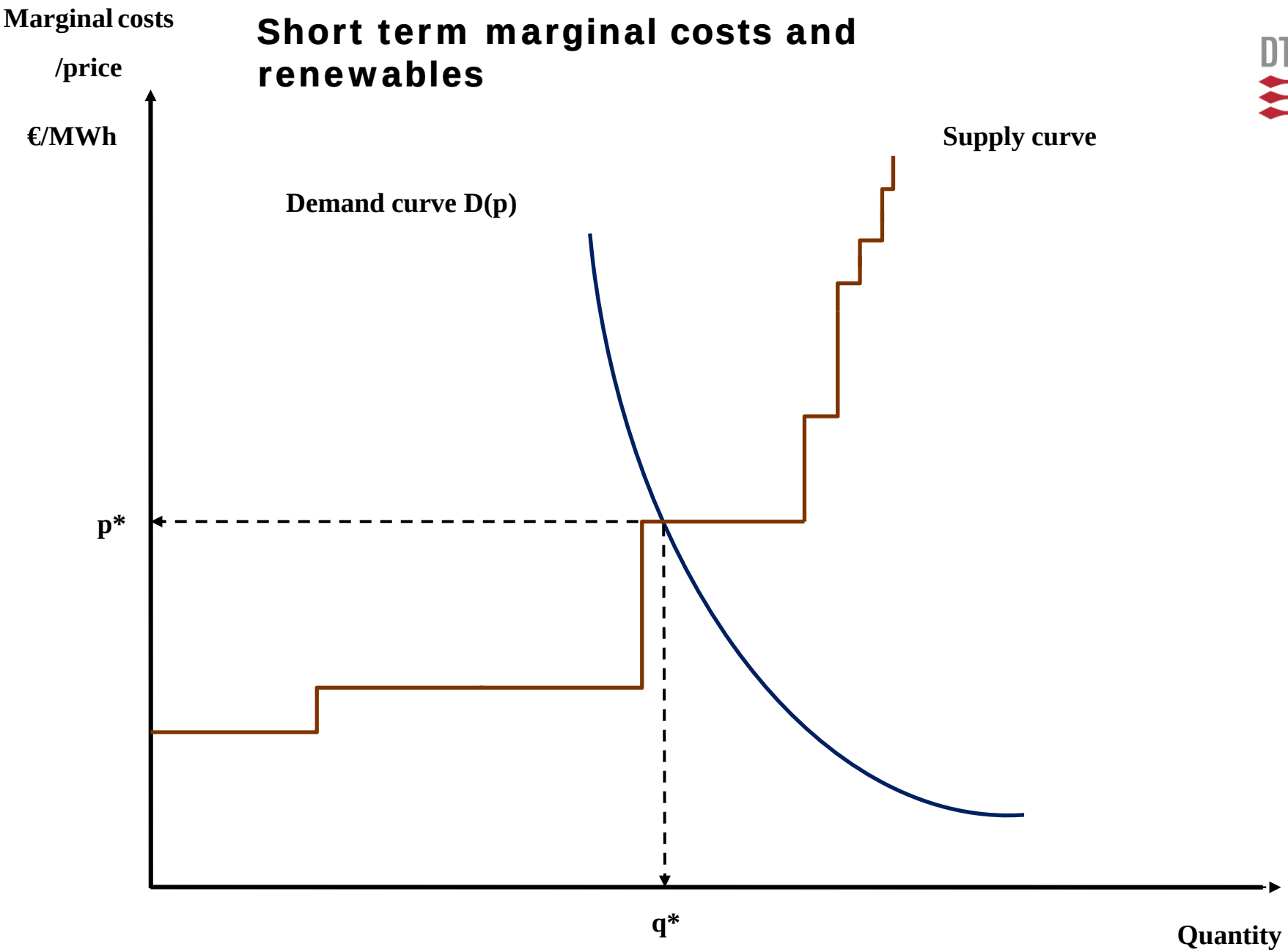


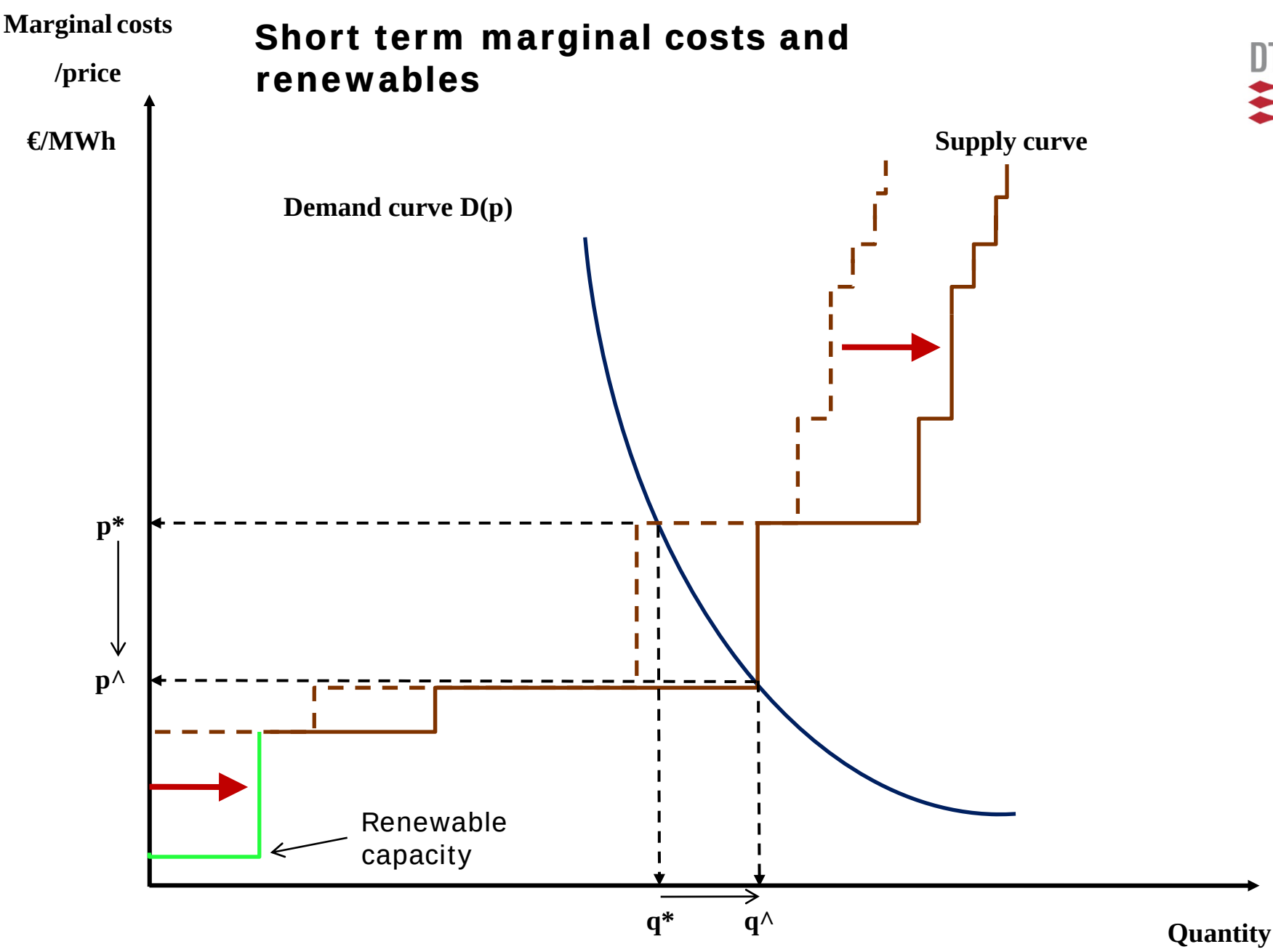
Short term marginal costs

- The supply curve in day ahead market is reflecting the short term marginal costs
- Technologies differ in the mix of variable and fixed costs
- Intermittent renewable generation has very low short term marginal costs
- Intermittent generation forms the lower left part of supply curve
- Variation in generation from renewables will thus shift the entire supply curve

Short term marginal costs and renewables



Short term marginal costs and renewables



Adding renewable capacity and the short term price effect

- Adding renewable capacity shifts supply curve to the right
- Prices are reduced – the size depends on shape of demand curve
- This means that prices are reduced the most when demand is high and the least when demand is low
- The effect is however not different from adding alternative cheap power, base load technologies with low marginal cost would also shift the supply curve to the right
- In most cases the effect for consumers is not as great (consumer prices have to bear the cost of the subsidy)
- In the long term lower prices will affect the short term supply curve by decommissioning of unprofitable old plants and the price effect will be reduced

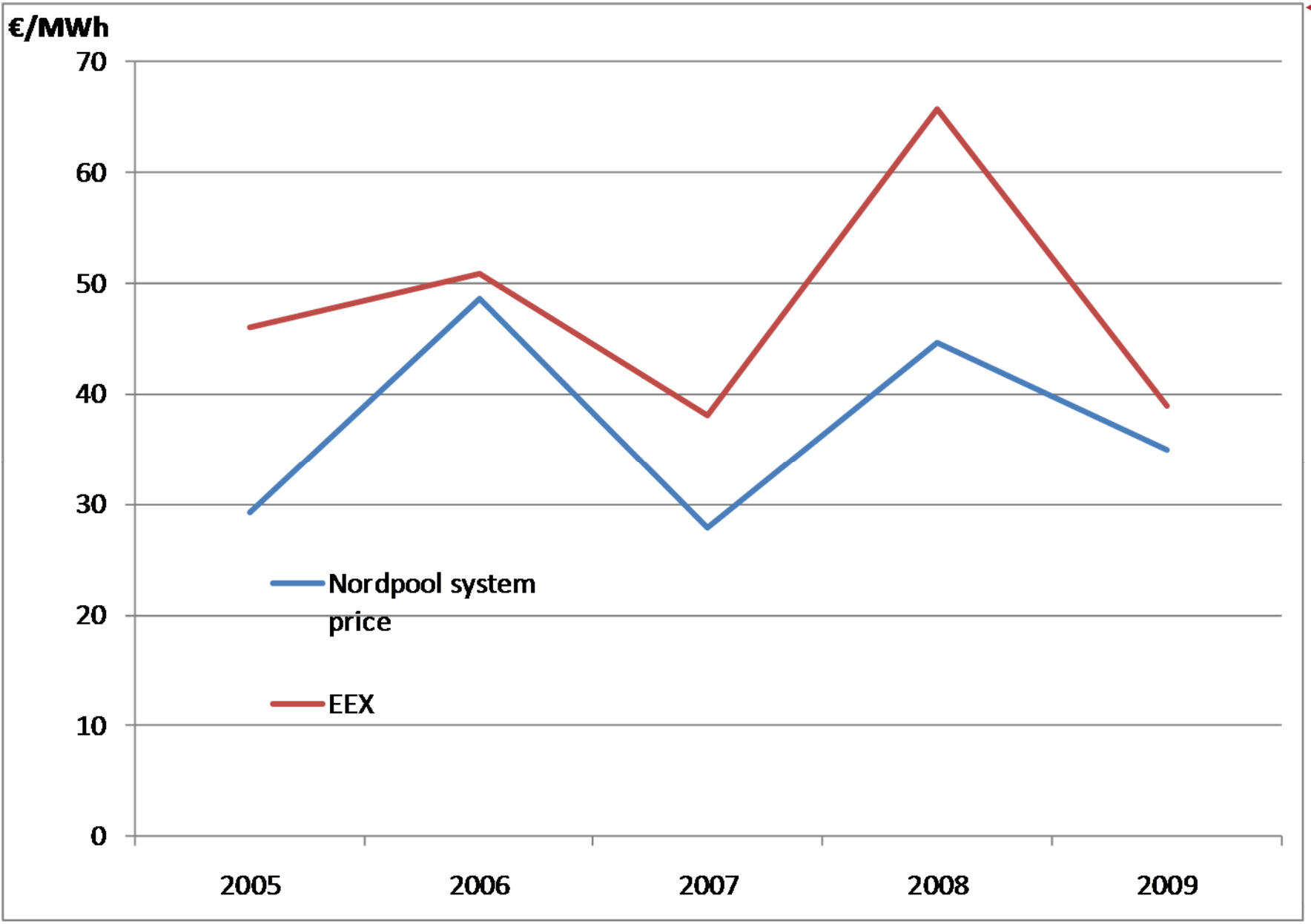
Electricity price level and volatility depends on demand variation and composition of power system

- Intermittent generation will affect prices most in systems with few flexible generation resources
- Intermittent generation will affect prices most if demand variation is large
- Price effect is also high if short term demand flexibility (elasticity) is low
- Intermittent generation and interaction with very flexible hydropower systems is an ideal situation
- Example: Danish wind and Norwegian hydropower

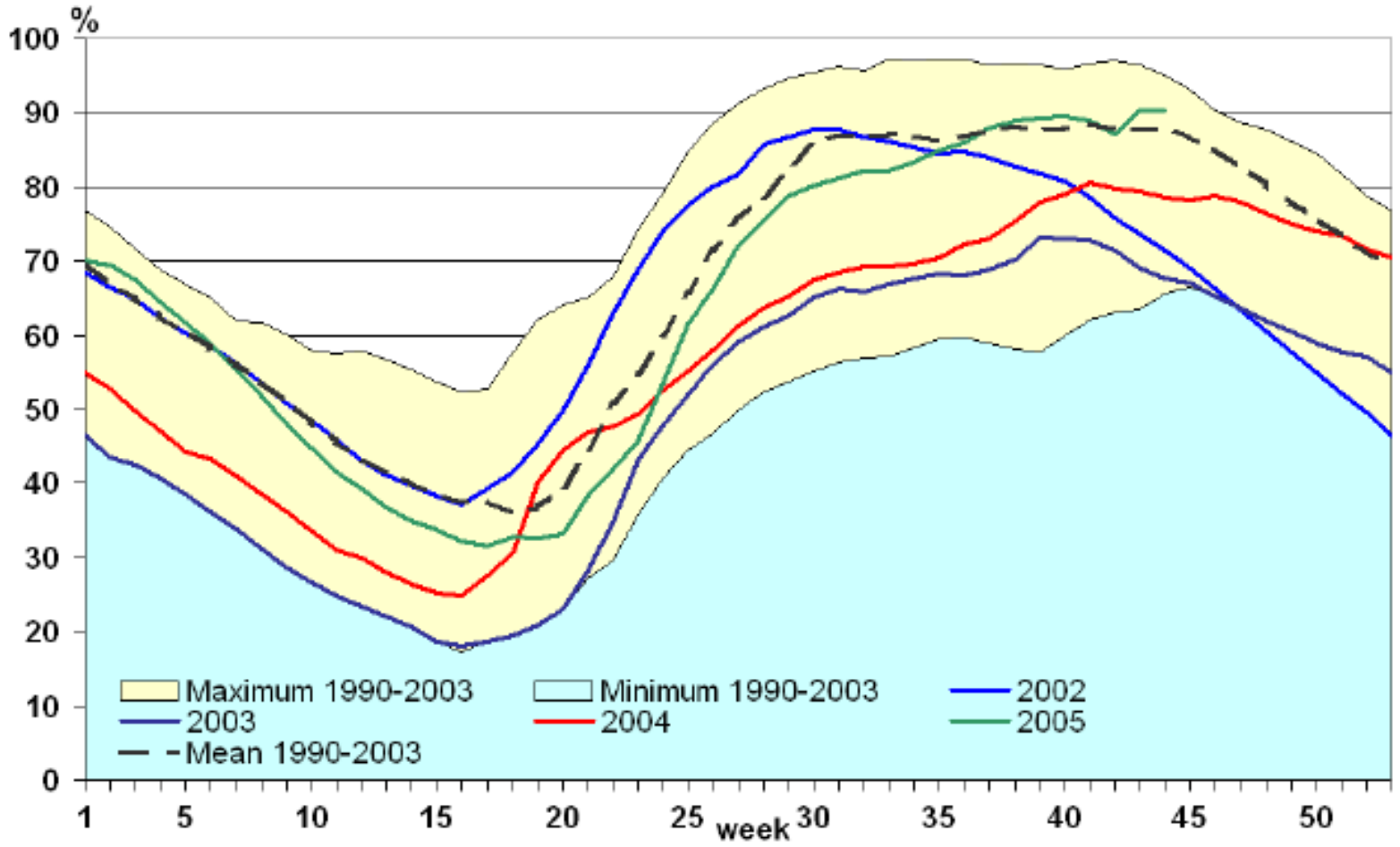
Price volatility

- Power prices vary on day ahead markets in line with demand variations and the composition of supply technologies
- Intermittent generation is generally seen as increasing price volatility because of variability and low predictability
- The annual price variation caused by wind which is the volatility that affects annual generator revenues and their corporate results is however not more important than the price and cost impacts from variation in fuel prices or annual precipitation for hydro
- Intermittent generation might even reduce volatility if the additional capacity added just adds to available generation capacity in the system and lowers the average price and make the price peaks less frequent

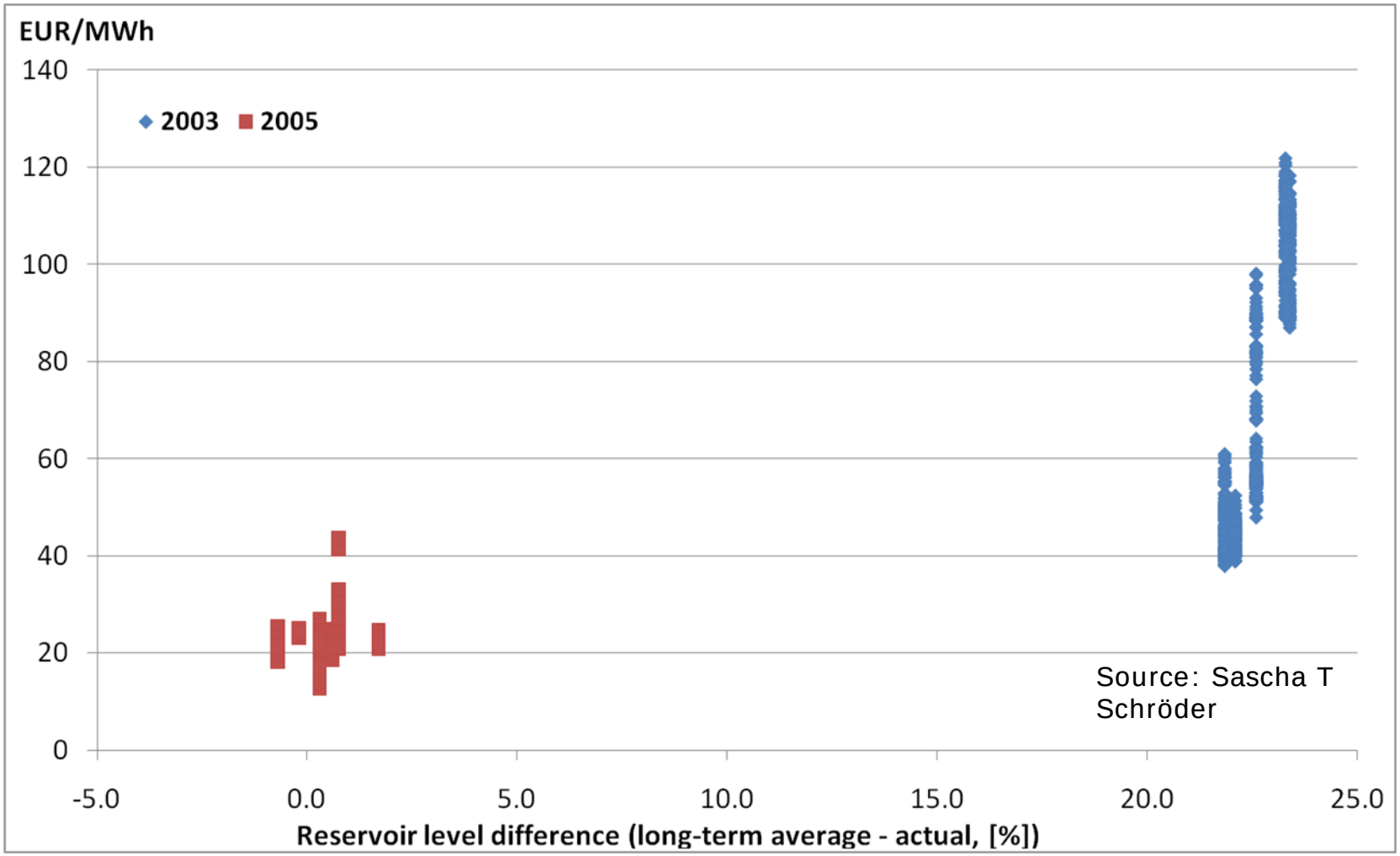
Annual price variation



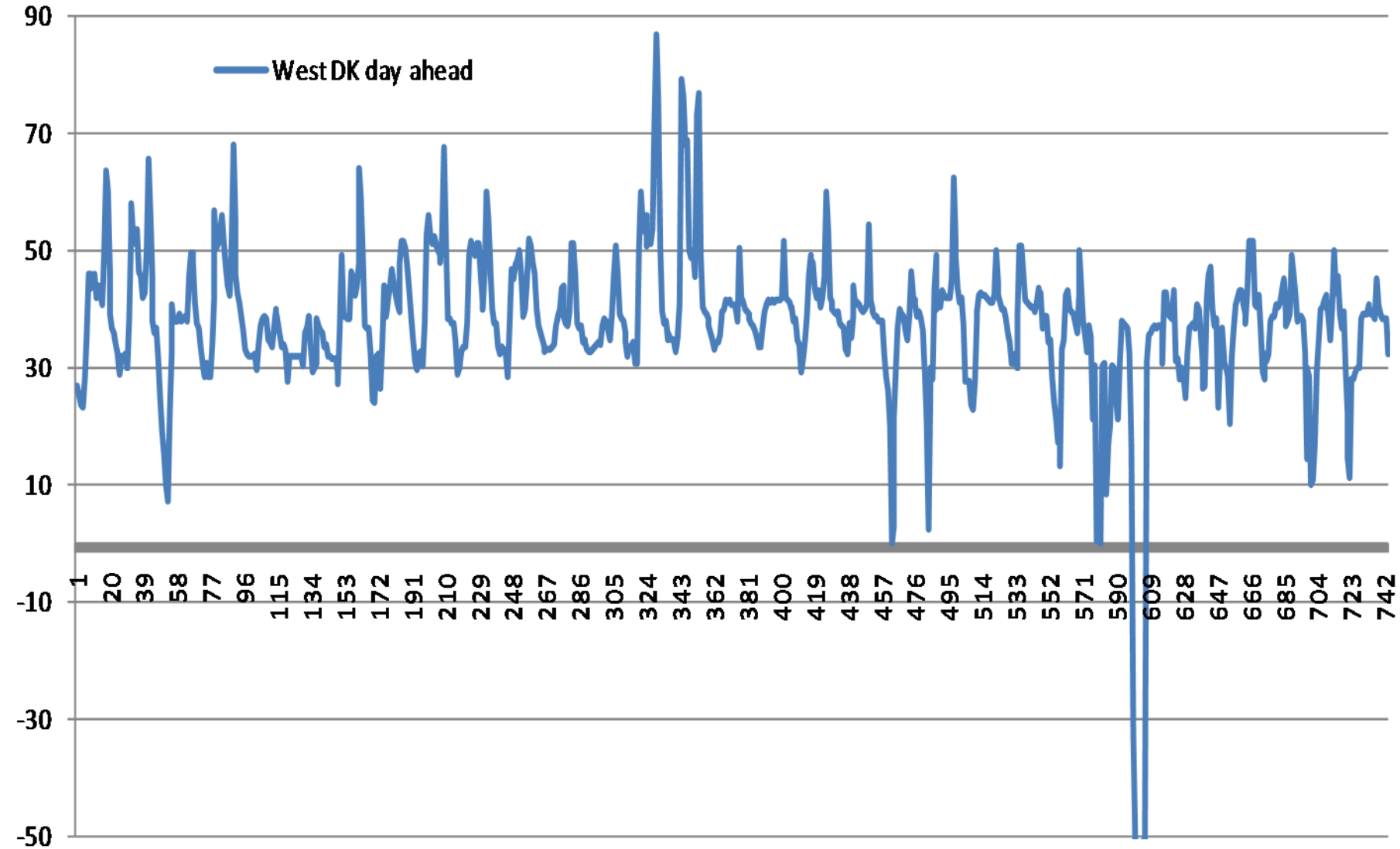
Norwegian reservoir levels and the impact on Nordic and Danish price and price volatility



Norway: Reservoir levels and prices

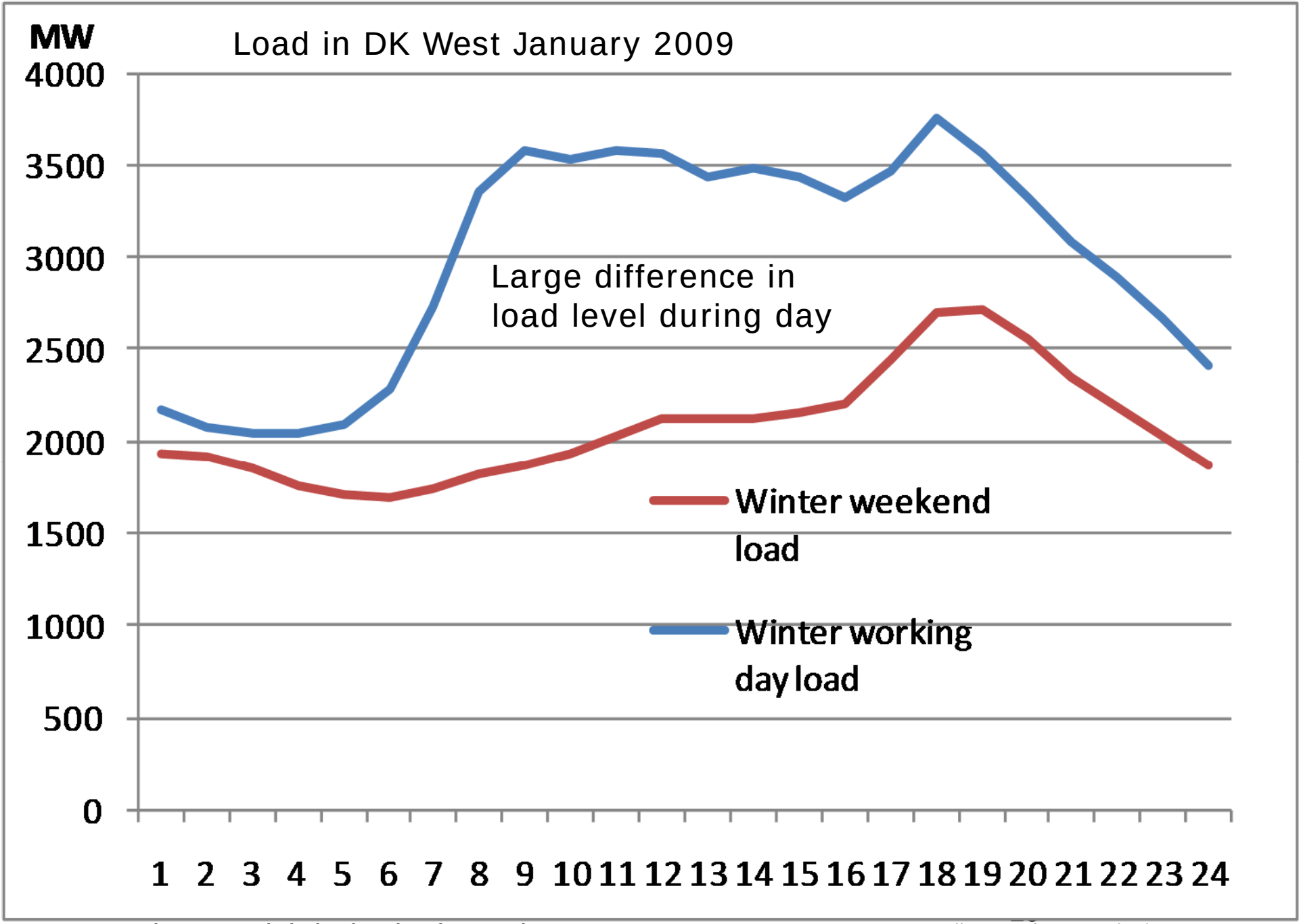


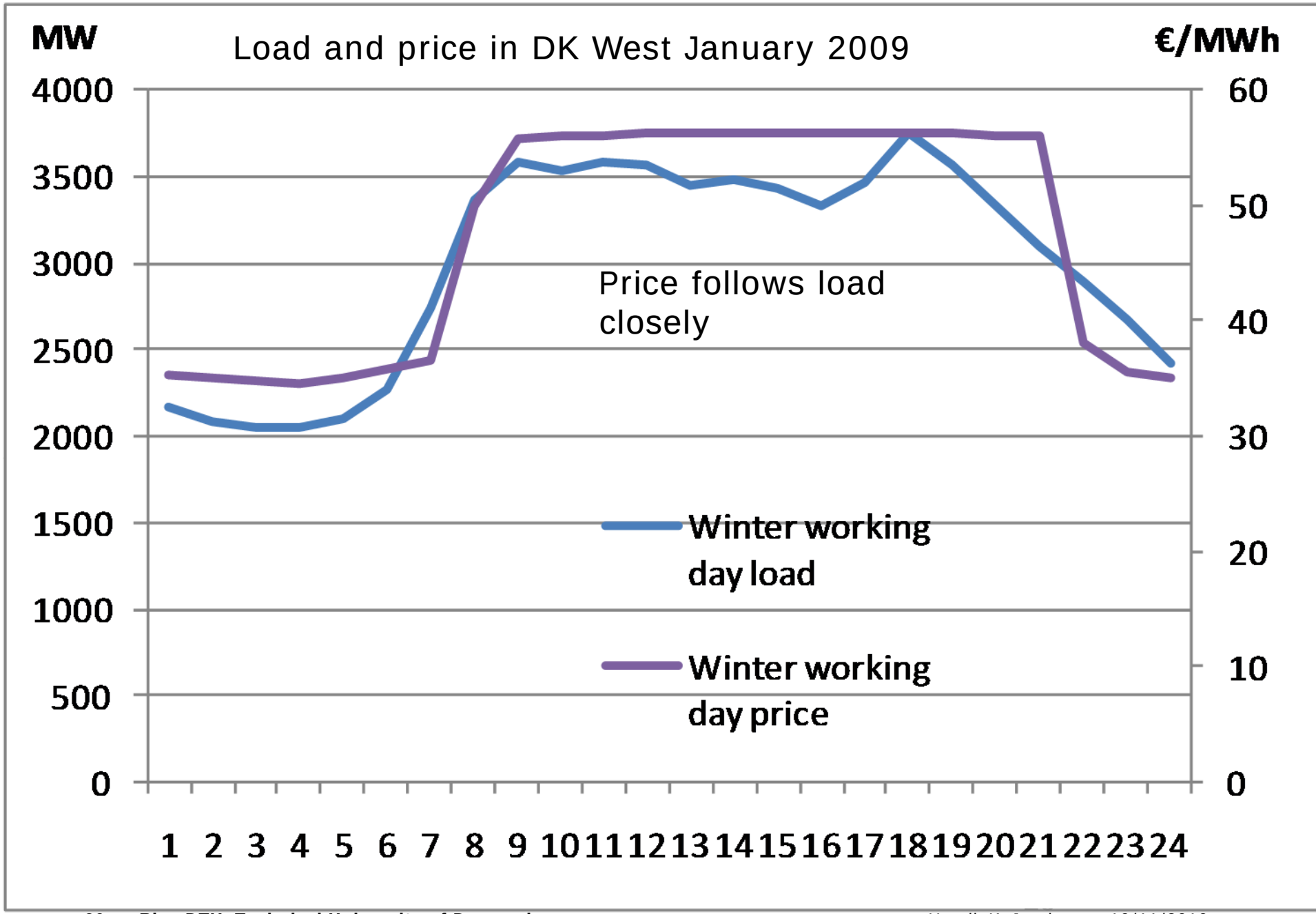
December 2009 hourly price

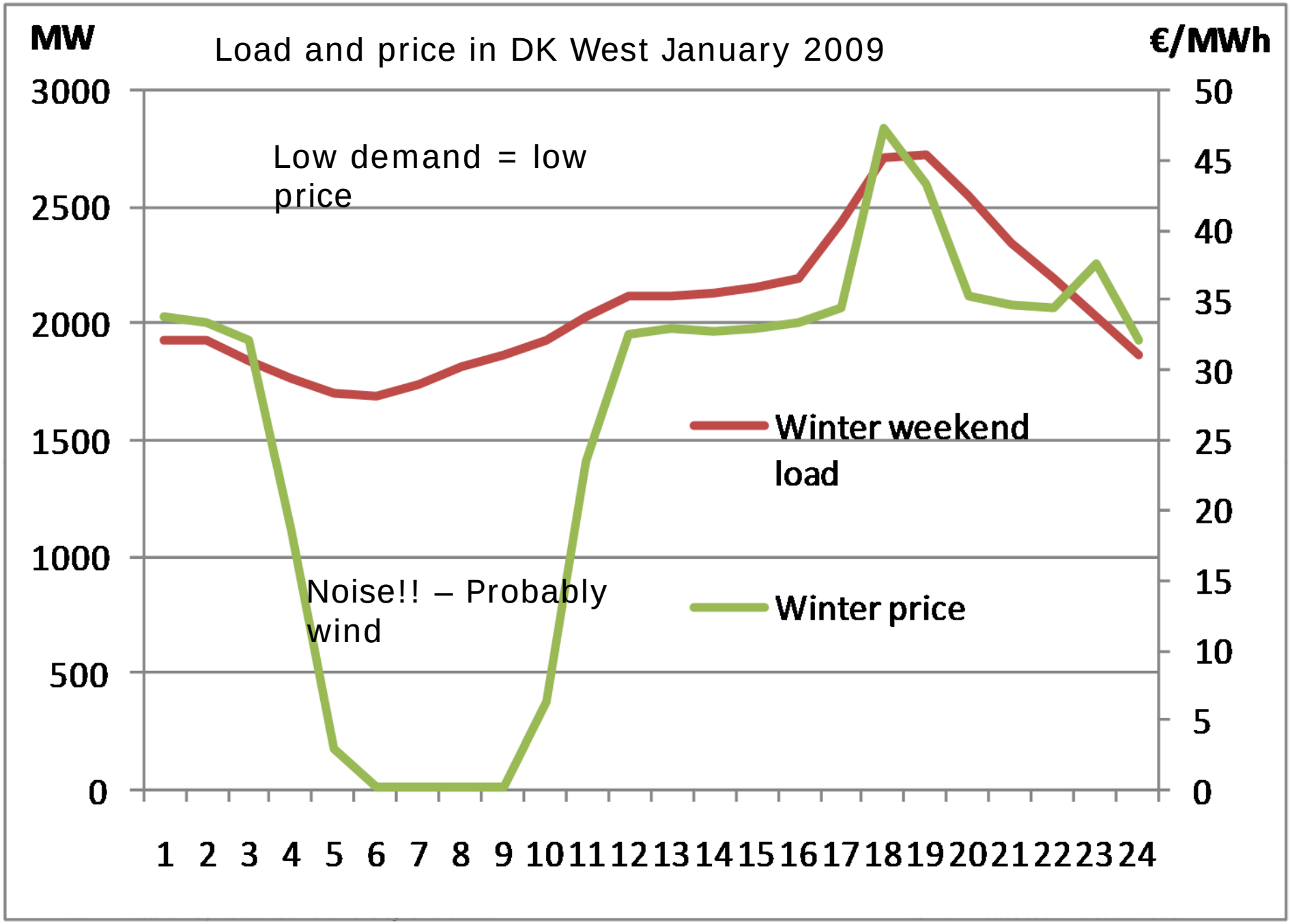


Price variation caused by load variation in DK market

- High load during daytime working days produce high prices
- Following graphs illustrate price and load interaction in DK West market with disturbances from supply curve shifts caused by wind

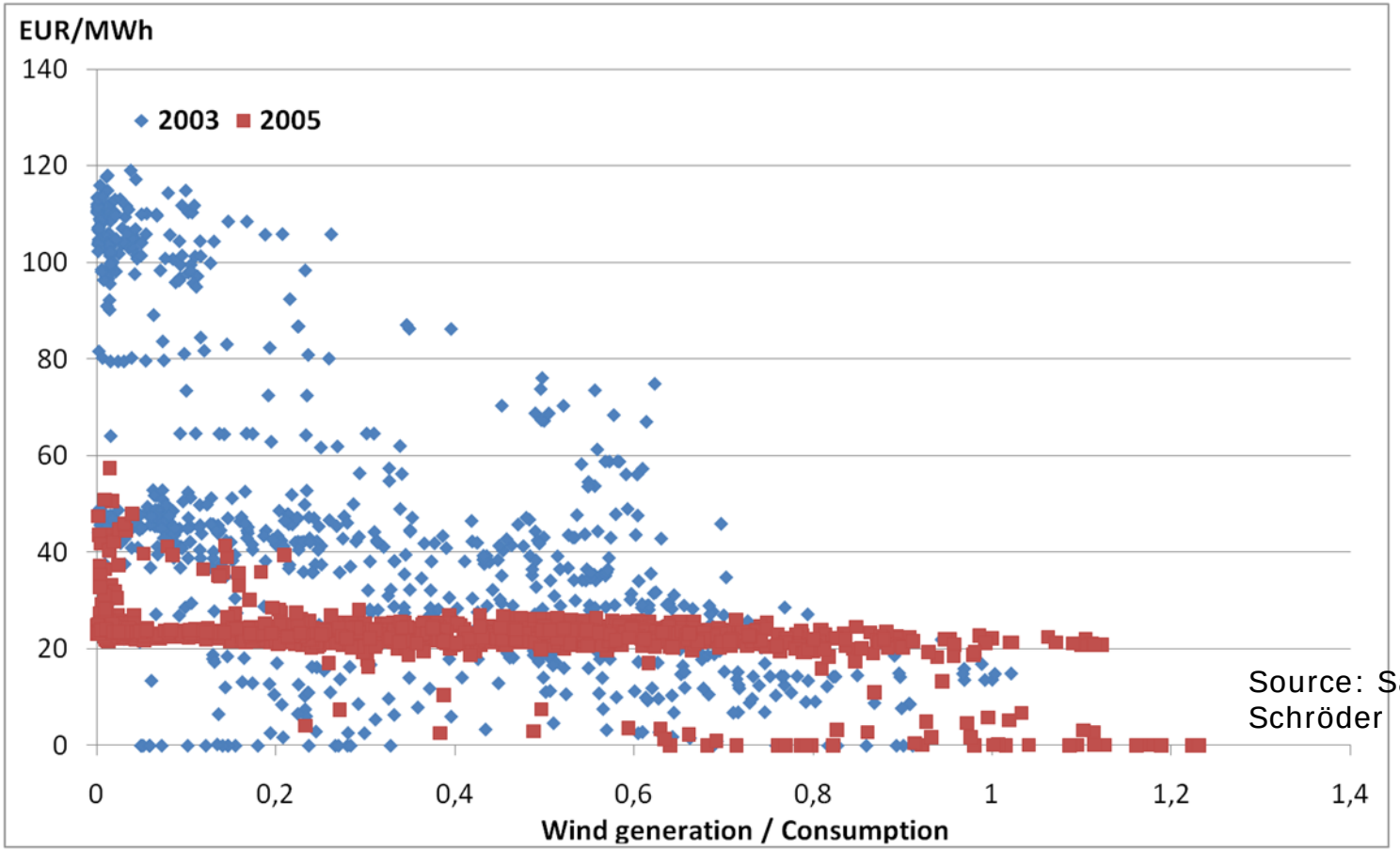

MW
Load in DK West January 2009
4000
3500
3000
2500
2000
1500
1000
500
0
Large difference in load level during day
Winter weekend load
Winter working day load
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


MW
Load and price in DK West January 2009
€/MWh
4000
3500
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
Price follows load closely
Winter working day load
Winter working day price
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


MW
Load and price in DK West January 2009
€/MWh
3000
2500
2000
1500
1000
500
0
50
45
40
35
30
25
20
15
10
5
0
Low demand = low price
Noise!! – Probably wind
Winter weekend load
Winter price
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Denmark-West: Wind and power prices

- comparison: January of both years



Source: Sascha T Schröder

Electricity price and renewable generator revenues

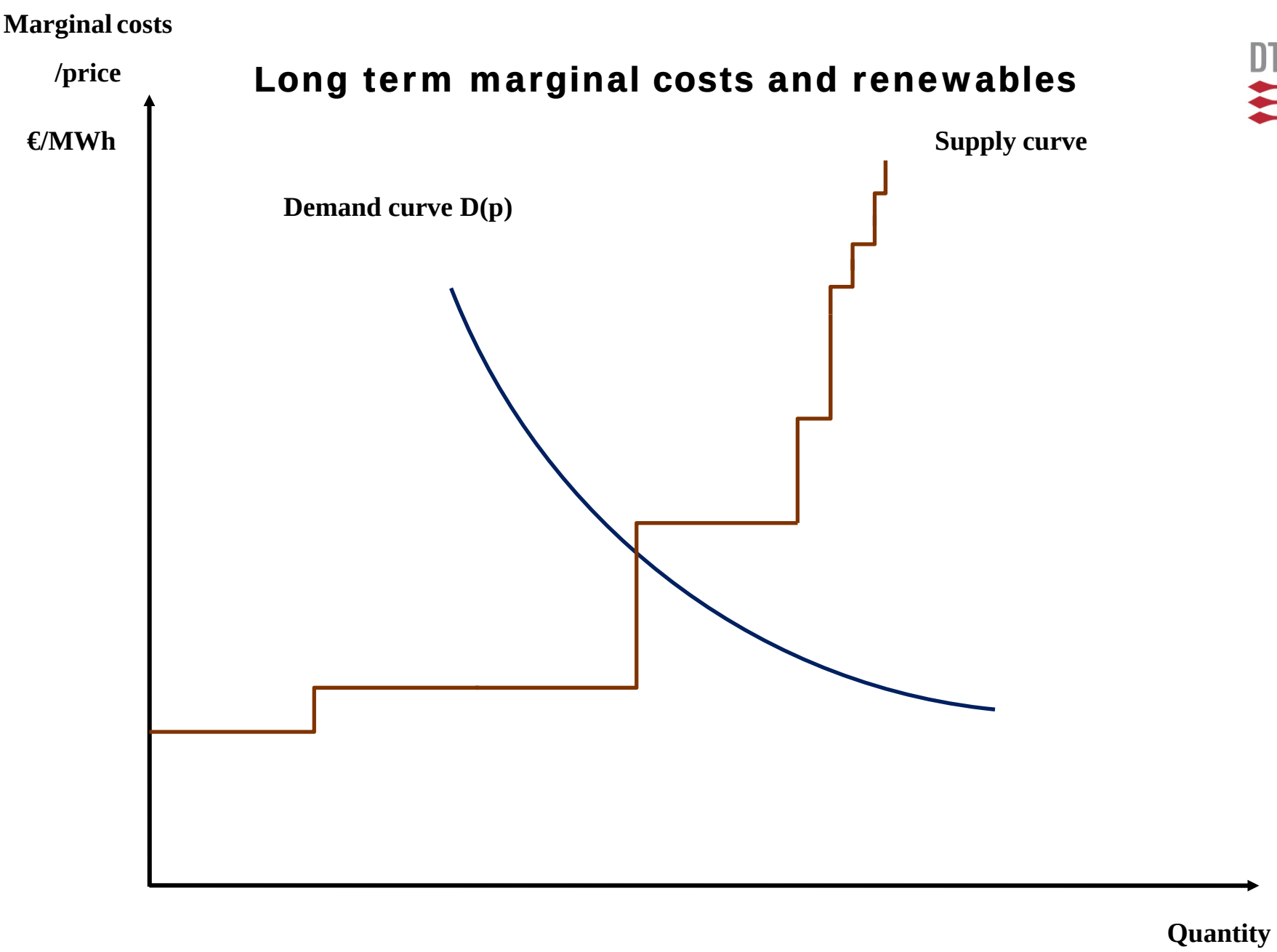
- Renewable intermittent generators are subsidised
  - feed-in tariffs
  - premiums
  - green certificates
  - investment grants or tax rebates

So what does prices matter?

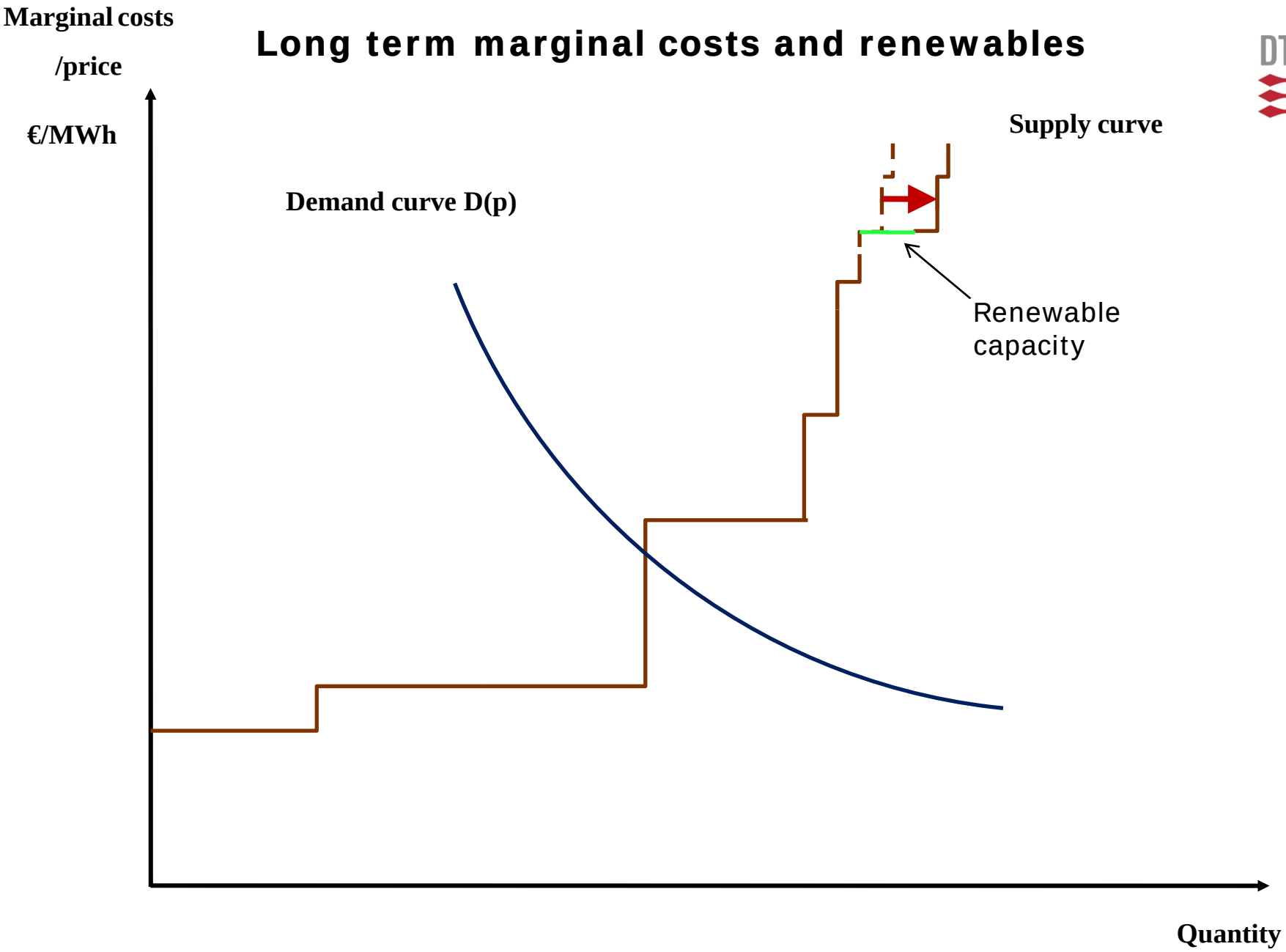
- First
  - premiums create some market dependence
  - fixed term (15 years 50000 full load hours) support and then 100% market!

- Secondly
  - Generators portfolio include intermittent generation and conventional generation
  - Theirs and competitors investment in intermittent generation will influence the price patterns of power markets and their total revenues

Long term marginal costs and renewables



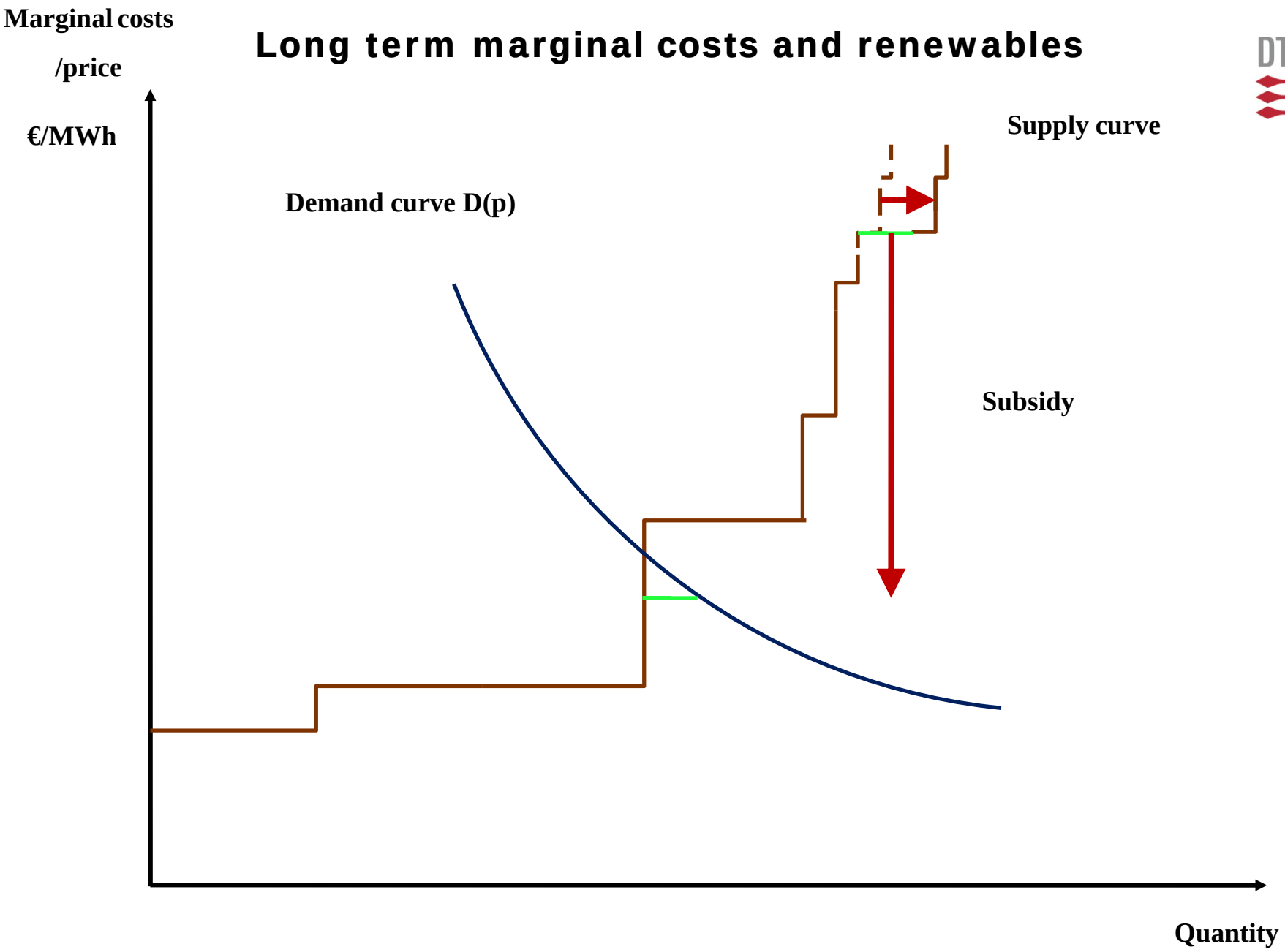
Long term marginal costs and renewables



Long term marginal costs

- Intermittent renewable technologies have **low short term** marginal costs *but* **high long term** marginal costs
- The long term supply curve is only affected at the top end (the top part shift to the right)
- Therefore they require financial support to compete as the preferred investment technology
- The investment in renewables affects the short term power prices downwards
- The investment incentive provided through the short term power markets are thus reduced and
- The dynamic response will be to reduce the conventional capacity in the longer term

Long term marginal costs and renewables

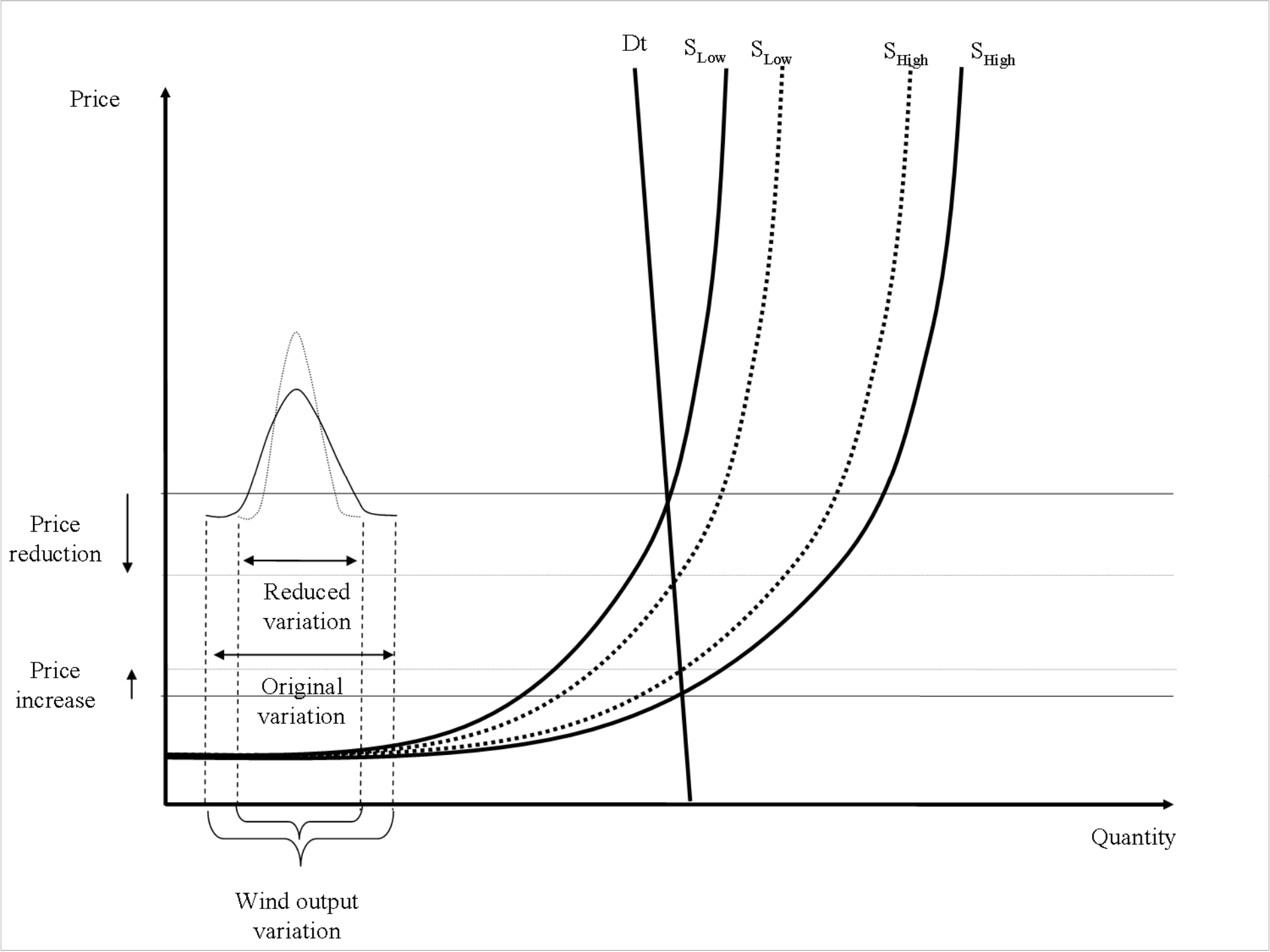


Intermittent generation and price effects of change in aggregate generation variation

- Variations in intermittent renewable generation is costly and efforts to reduce variability are suggested as for example, aggregation of different types of intermittent, spreading the expansion to larger areas with less wind speed correlation, encouraging demand response options etc
- the main efficiency/cost reducing argument will be related to less capacity requirements and better average fuel efficiency in the long term (+technical problem mitigation)

- But what about the short term effect for the market?

- Assume that less variability will reduce the max intermittent output and increase the minimum output identically (symmetrical reduction of distribution)
  - Lower maximum generation will increase prices
  - Higher minimum generation will reduce prices
  - What is the net effect and the distribution?


Dt
S_{Low}
S_{Low}
S_{High}
S_{High}
Price
Price reduction
Price increase
Reduced variation
Original variation
Wind output variation
Quantity

Prices will tend to be reduced more than they are increased –

- For the average generator this is not attractive

- For the peak plants this is even less attractive
- **But for wind generators** this might even be a positive impact as they have high output at times of low prices and low output at times of high prices

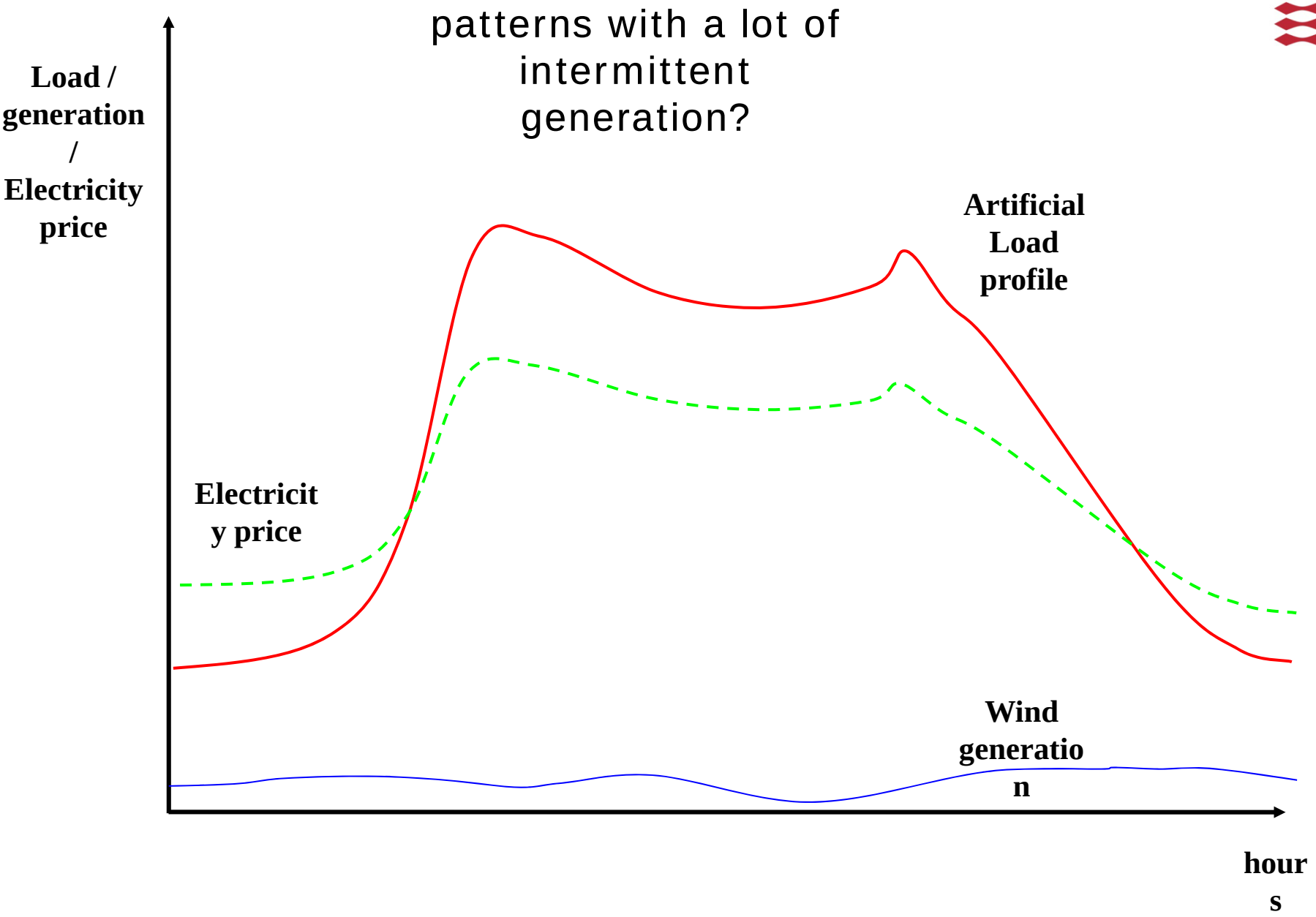
- Therefore less variation might even increase the market part of their revenue in combination with better capacity value characteristics

Intermittent generation and balancing markets

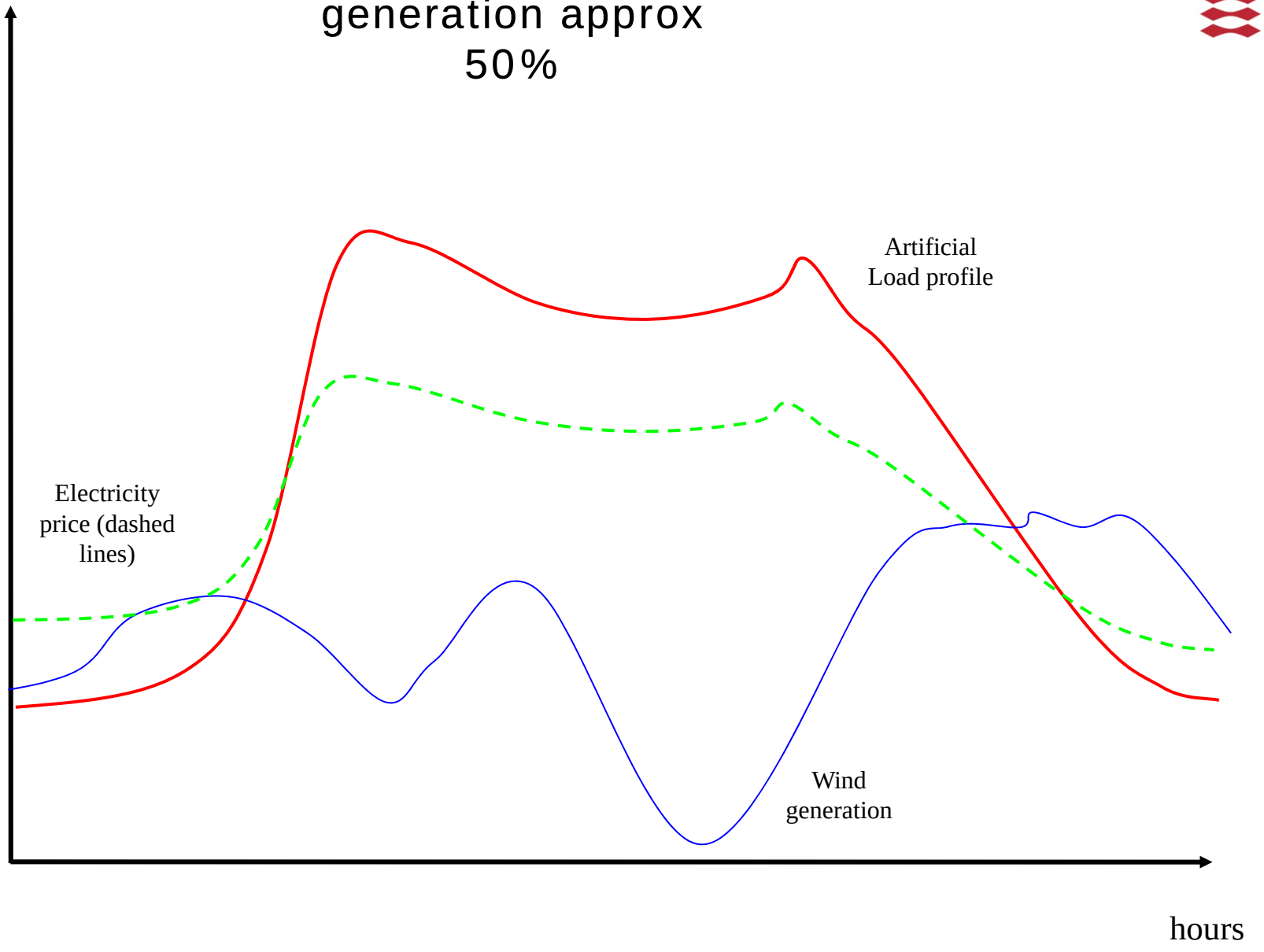
- In some cases intermittent generation has also been made balance responsible - they have to pay balancing costs (DK with average based compensation)
- With large price effects in day ahead markets this create additional incentives for arbitrage in the day ahead and balancing markets
- With power prices that are negative at times and frequently are quite low in Denmark and Northern Germany there is an incentive to reduce the supply at day ahead and thereby reduce the balancing costs
- This could be efficient if the generators with the highest marginal costs in the day ahead market reduce their supply In the case of high stop and start costs of conventional plants it could even be the best option to reduce wind supply – but the market should provide the signal

How much intermittent generation is sufficient to affect prices?

What happens to price patterns with a lot of intermittent generation?

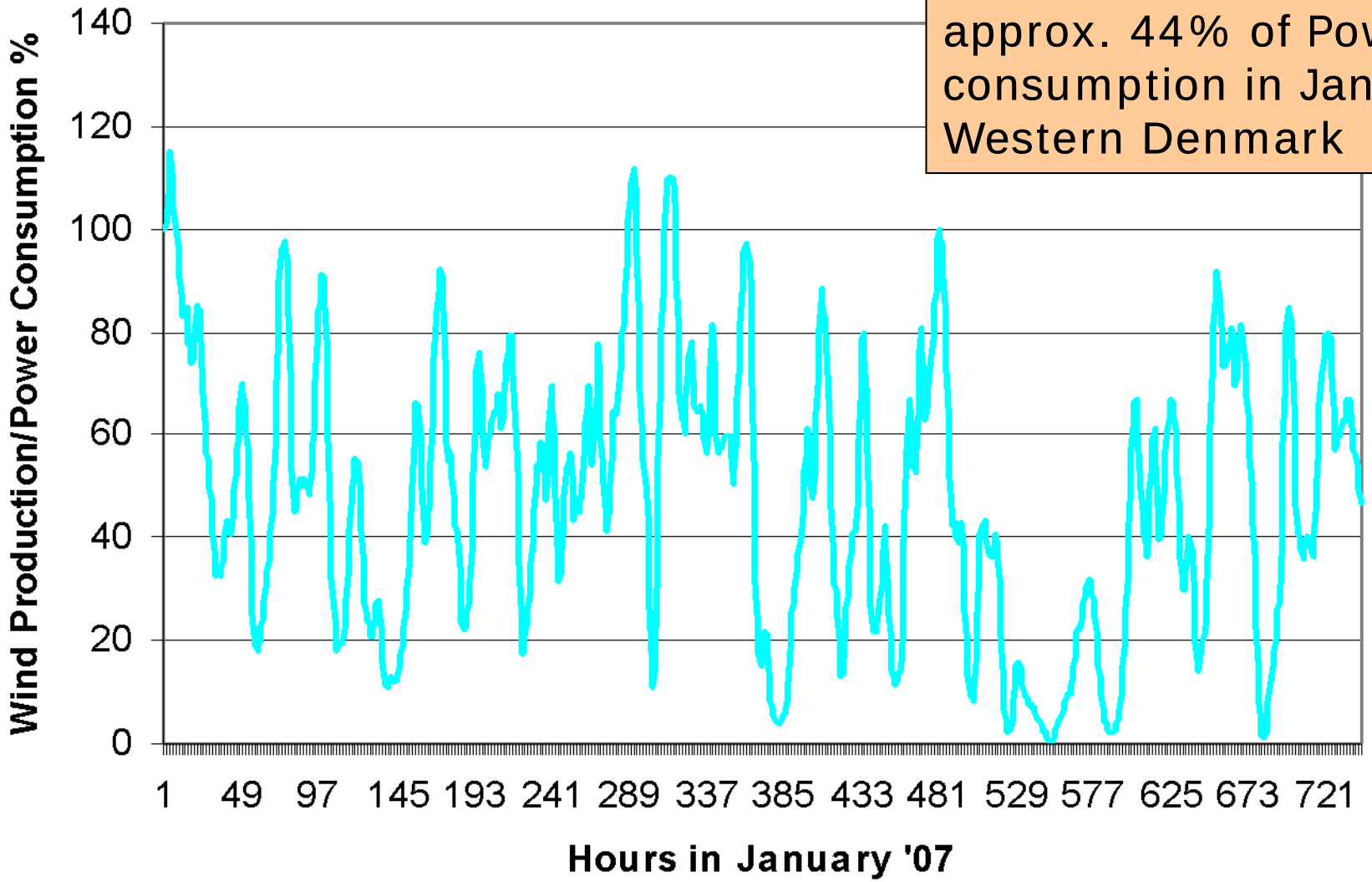


Upscaled wind generation approx 50%



Wind power in Western Denmark

Wind Power covered approx. 44% of Power consumption in January in Western Denmark



Demand response – effect on load and prices

- How would the demand response affect the situations where intermittent generation has an impact on prices?
- Load shifting (hours)
- Low prices increase demand (technologies)
- Excess generation and restricted export (interconnection capacities) – reduce the value of interconnection (substitute)

Thank you for your attention!

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